

A coastal survey in the southern part of the Palaeoproterozoic Rinkian fold belt, central West Greenland

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A brief but potentially important part of the 2001 field investigations in the Precambrian of West Greenland (van Gool *et al.* 2002, this volume) was devoted to the southernmost part of the Palaeoproterozoic Rinkian fold belt east of Disko Bugt (Fig. 1). From 9–17 August the five authors carried out a reappraisal of critical Archaean and Proterozoic relationships and collected samples for precise geochronological studies. The principal aims are to date the main Rinkian tectonic and metamorphic events in this region as precisely as possible and compare them with the evolution of the Nagssugtoqidian orogen to the south (see van Gool *et al.* 2002, this volume, fig. 1). The vessel M/S *Søkongen* provided logistic support; a helicopter provided transport to Nunatarsuaq.

Geological background

The Archaean continental terrains in West and East Greenland, north-eastern Canada, Scotland and Scandinavia were gradually amalgamated during a series of major Palaeoproterozoic orogenic events to form one of the earliest large continents on Earth. Recent structural and geochronological studies have significantly improved the correlation between the individual orogens and the understanding of the overall plate-tectonic framework (e.g. Clowes *et al.* 1999), but there remain significant geographical, chronological and structural uncertainties. One of these concerns the boundary zone between the Nagssugtoqidian and Rinkian orogenic belts in central West Greenland (van Gool *et al.* 2002, this volume, fig. 1). It is quite possible that the two belts formed contemporaneously within a common, or at least related, plate-tectonic setting. However, the structural styles of the two belts are different; at least one part of the contact region between the two belts only displays very weak Palaeoproterozoic reworking, and only a rudimentary geochronological data base is currently available for the Rinkian belt.

Recent geochronological and structural studies in the southern and central Nagssugtoqidian orogen by the Danish Lithosphere Centre have established an accurate and robust time-frame for the accretion of its Archaean magmatic elements, the Palaeoproterozoic magmatic arc component, its subsequent tectonic accretion, and final stabilisation (Connelly *et al.* 2000; Willigers *et al.* 2002). These insights are being largely corroborated by ongoing work in the northern Nagssugtoqidian orogen (van Gool *et al.* 2002, this volume).

Such constraints are not yet available for the Rinkian fold belt (Henderson & Pulvertaft 1987; Grocott & Pulvertaft 1990; Kalsbeek *et al.* 1998). During the most recent investigations by the Survey conducted in 1988–1991 (Kalsbeek 1999), it was established that Rinkian structural reworking was strong in eastern Nuussuaq, southern Arveprinsen Ejland and areas to the east. In contrast, the intervening Ataa domain was largely unaffected by reworking (Fig. 1; Kalsbeek *et al.* 1988; Escher *et al.* 1999; Garde & Steenfelt 1999a, b; Grocott & Davies 1999). An Ar-Ar and K-Ar geochronological study confirmed this general interpretation but with a broad spread of ages (Rasmussen & Holm 1999). A few ion probe U-Pb zircon ages, whole-rock Pb-Pb and Rb-Sr ages and model Sm-Nd ages showed that both the Atâ tonalite and adjacent supracrustal lithologies in the Ataa domain were magmatically accreted at 2800 Ma (Kalsbeek & Taylor 1999; Nutman & Kalsbeek 1999). However, the age histories of the reworked, supposedly Archaean basement of Nuussuaq and the Palaeoproterozoic reworking north and south of the Ataa domain have yet to be unravelled.

In this contribution, we present a summary of our main objectives in the southern part of the Rinkian fold belt and relate them to the geological problems outlined above. An overview of the southern part of the Rinkian belt can be found in Garde & Steenfelt (1999a).

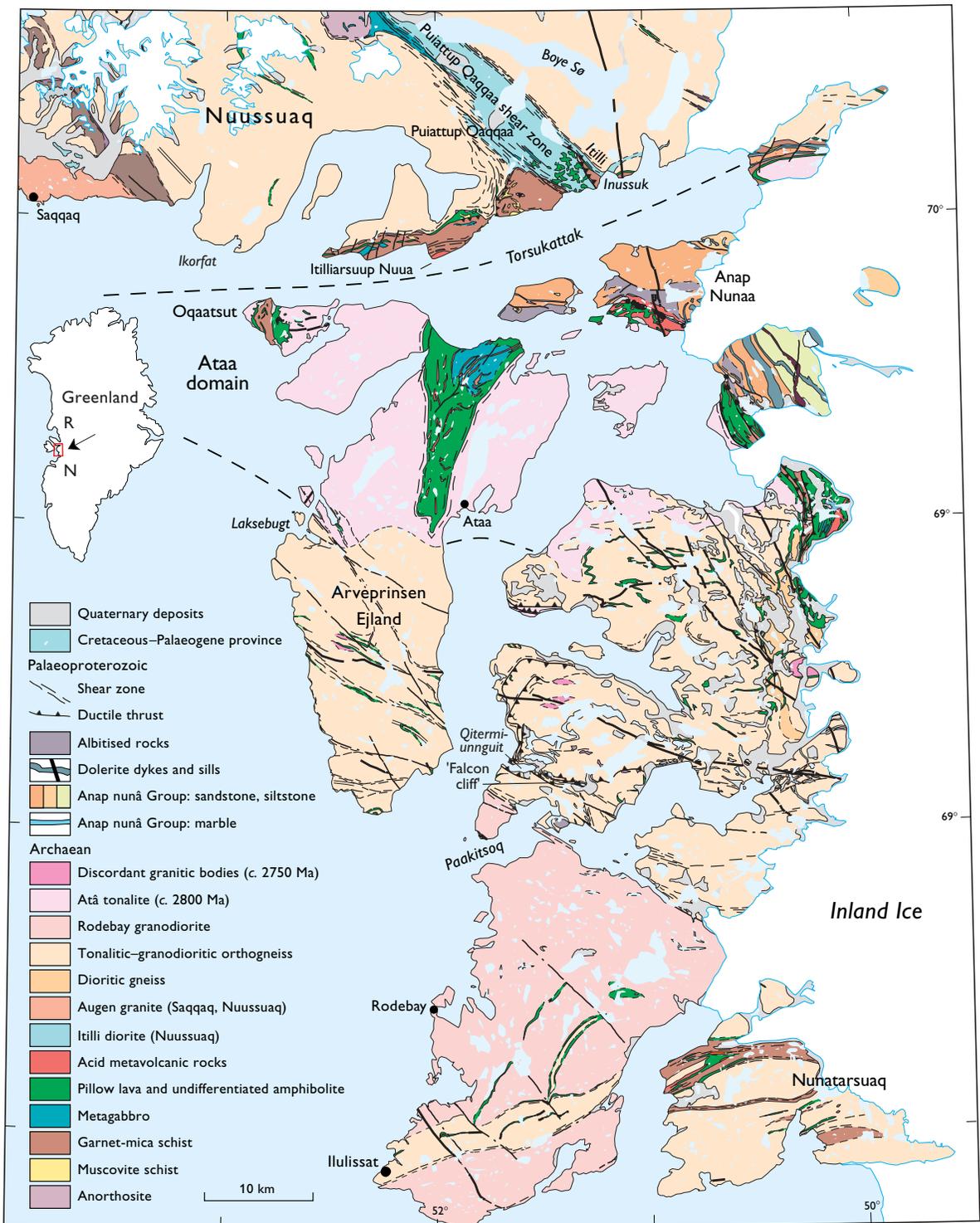


Fig. 1. Geological sketch map of the area north-east of Disko Bugt with place names used in the text, modified from Garde (1994). **Dash lines:** domain boundaries. **Filled circles:** towns, settlements. **Open circle:** abandoned settlement. **Dash-dot lines:** faults. **N** and **R** on the inset map of Greenland denote the Nagssugtoqidian and Rinkian belts, with the map area at the **arrow** (also shown on van Gool *et al.* 2002, this volume, fig. 1).

Archaean acid metavolcanic rocks and the Torsukattak shear zone, south coast of Nuussuaq

The Survey's field work in Nuussuaq in 1988–1991 was largely restricted to helicopter reconnaissance; due to difficult ice conditions and lack of a suitably large boat, the south coast was not mapped. Nevertheless, a preliminary lithostratigraphy of the main, supposedly Archaean supracrustal sequences in southern Nuussuaq was established (Garde & Steenfelt 1999a), and two major Proterozoic shear zones were proposed: (1) the well-exposed, NW–SE-trending *Puiattup Qaqqaa shear zone* in southern Nuussuaq, and (2) the *Torsukattak shear zone*, a largely unexposed younger extensional shear zone along the fjord Torsukattak with oblique downthrow to the south-east (Fig. 1). The existence of the latter shear zone was mainly inferred from numerous inland observations of intense SE-plunging extension lineations, apparent tectonic reworking of the Puiattup Qaqqaa shear zone towards Torsukattak, and an abrupt decrease in the overall metamorphic grade between southern Nuussuaq and the Ataa domain (for details see Garde & Steenfelt 1999b).

In 2001, it was possible to study the outcrops along the coast of Nuussuaq by boat in spite of much ice (Fig. 2). An acid metavolcanic rock with pale, fine-grained volcanic clasts (Fig. 3) from a previously reported supracrustal sequence north of Itilliarsuup Nuua (Fig. 1; Garde 1994) was sampled in order to obtain a depositional age for the metavolcanic rock by U-Pb dating of its igneous zircons (using the conventional thermal ionisation method, TIMS); this will also provide a minimum age for the underlying Nuussuaq gneisses, and will allow us to compare the timing of volcanism at the continental margin of southern Nuussuaq with the arc-type volcanism in the Ataa domain, which was previously dated at *c.* 2800 Ma (Kalsbeek & Taylor 1999). In addition, the zircon U-Pb system might also provide a discordia age for the Torsukattak shear zone.

During a boat traverse of the excellently exposed, SSE-dipping acid metavolcanic and associated metasedimentary rocks we observed asymmetric volcanic clasts and garnet porphyroclasts within the intense, SE-plunging LS fabric. The asymmetric fabric elements clearly indicate relative downthrow of the southern hanging wall towards the south-east along the steep lineation (Fig. 4), corroborating Garde & Steenfelt's (1999b) interpretation that the Torsukattak structure is a major, oblique extensional shear zone. It was previously noted in inland areas that the intensity of the LS strain fabric



Fig. 2. M/S *Søkongen* in the ice-filled waters of Torsukattak, north-west of Anap Nunaa.



Fig. 3. Fragmental acid metavolcanic rocks at Itilliarsuup Nuua. Pencil for scale.

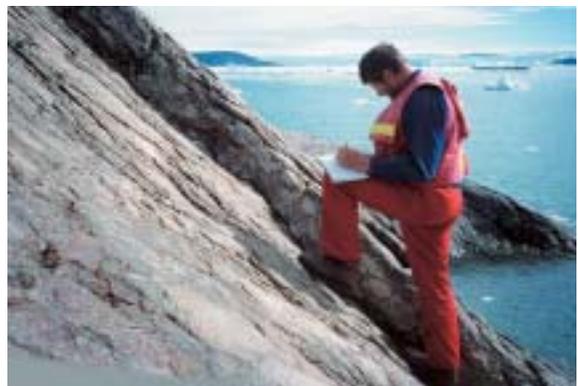


Fig. 4. Asymmetric fabric elements (volcanic clasts) at Itilliarsuup Nuua, indicating relative downthrow of the southern (right-hand) side of the Torsukattak shear zone. View eastwards along the south coast of Nuussuaq.

increases towards the south. We observed that the strain intensity reaches a maximum about 50 m from the point of Itilliarsuup Nuua, where ultramylonitic rocks occur. Further south, towards the point itself, the intensity of the LS fabric decreases significantly. It is concluded that the central part of the Torsukattak shear zone is probably not hidden in the fjord as hitherto believed, but may be located close to Itilliarsuup Nuua.

Other supracrustal rocks of supposed Archaean and Palaeoproterozoic age

Garnet- and biotite-rich metasedimentary rocks at Inussuk near the head of Torsukattak, Oqaatsut and on Nunatarsuaq were sampled for U-Pb ion probe studies of detrital zircons and microtextural and metamorphic studies. In addition, dating of metamorphic minerals may allow determination of the cooling path (U-Pb: titanite, apatite; Rb-Sr: biotite, muscovite). Samples of low-grade sedimentary rocks from the Anap nunâ Group were also collected on northern and south-eastern Anap Nunaa.

Archaean basement of southern Nuussuaq and in the Ilulissat/Jakobshavn area

Representative samples of orthogneiss and granitic rocks were collected from various parts of the Archaean basement in the southern Rinkian belt and the border region to the Nagssugtoqidian orogen as part of an ongoing regional age characterisation of the Archaean basement in West Greenland. The sampled units include grey tonalitic orthogneiss and associated younger granitoid phases at the embayment 2 km west of Ikorfat, granodioritic augen gneiss c. 5 km west of Saqqaq, Itilli diorite north of inner Torsukattak, grey tonalitic orthogneiss at western Arveprinsen Ejland at Laksebugt, Ilulissat harbour and Ilulissat airport, and Rodebay granite at Rodebay (Fig. 1).

North- to west-directed Proterozoic thrusting of Archaean orthogneisses at Paakitsoq

In the area south of the Ataa domain, which was affected by significant Palaeoproterozoic reworking, Escher *et al.* (1999) reported major low-angle ductile imbrication of



Fig. 5. Mylonitised orthogneiss with asymmetric porphyroclasts and extension lineation, north coast of Qitermiunnguit.

Archaean orthogneisses in the vicinity of Paakitsoq. The main thrusting is envisaged to have occurred during an early phase of Proterozoic deformation, and according to Escher *et al.* (1999) the predominant movement direction of the thrusts was westwards. The thrusting event was followed by open to tight folding, and the thrusts were reactivated during the emplacement of a suite of up to c. 100 m thick mafic sills. These were commonly emplaced along thrust planes and were subsequently boudinaged and their margins deformed during continued movement along the thrusts (Escher *et al.* 1999, table 1). The sills and their host rocks are cut by dolerite dykes as well as thin lamprophyre dykes and sills; the latter were dated at c. 1750 Ma by Larsen & Rex (1992).

It is of critical importance for the correlation between the Rinkian and Nagssugtoqidian belts that a comparison can be made between the timing of the Rinkian west-directed thrusting and the main crustal shortening event in the central Nagssugtoqidian orogen at c. 1860–1820 Ma (Connelly *et al.* 2000). Therefore, it is important to determine as precisely as possible when the main episode of thrusting at Paakitsoq prior to the sill emplacement took place. Our attention was focused on the orthogneisses at Qitermiunnguit and on the coast of north-eastern Paakitsoq (Fig. 1) which are readily accessible and in structural continuation with those at the ‘Falcon cliff’ of Escher *et al.* (1999, fig. 8). At both localities subhorizontal, upper greenschist to lower amphibolite facies high-strain zones up to a few metres

thick, which are commonly ultramylonitic, are separated by up to *c.* 100 m thick zones of much less deformed rocks. In the high-strain zones there are abundant, well-developed, asymmetric δ - and σ -shaped K-feldspar and plagioclase porphyroclasts within the LS fabric (Fig. 5), which is dominated by an intense, shallowly east-plunging extension lineation. It was easy to confirm the main westerly transport direction previously reported from other localities, e.g. at 'Falcon cliff'. Several orthogneiss samples were collected for U-Pb zircon geochronology: we hope to date the intense ductile deformation by means of precise lower concordia intercepts.

The *c.* 1650 Ma Melville Bugt dyke swarm at inner Torsukattak

In order to close the present gap in the existing data set of palaeomagnetic poles used to constrain Palaeoproterozoic to Mesoproterozoic plate reconstructions of Laurentia and Baltica (Buchan *et al.* 2000, 2001), a *c.* 100 m wide dyke belonging to the Melville Bugt dyke swarm of North-West Greenland and its contact rocks were sampled in inner Torsukattak. This particular dyke has a strike length of 400 km and was previously studied by Kalsbeek & Taylor (1986), who obtained a Rb-Sr age of 1645 ± 35 Ma. In addition to a sample set for the palaeomagnetic studies, a very large sample was collected from the dyke centre in the hope of retrieving magmatic zircon or baddeleyite for precise dating.

Concluding remarks

The survey north-east of Disko Bugt initiated in 2001 is a geochronological, structural and metamorphic study that aims to update understanding of the Rinkian orogen and its position in the contemporaneous framework of Palaeoproterozoic orogens in Greenland and eastern Canada. In 2002, with support from the Carlsberg Foundation, the survey will be extended into the central part of the Rinkian fold belt.

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